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The plot so far succeeds that Hamlet is mortally wounded, but he does not die before he has killed Laertes, and finding the “anointed” weapon in his hand, and coming death giving him no time to reason or reflect, he at last kills the king.

Heaven has forestalled him, however, for the real vengeance falls when the queen drinks of the poison prepared for her son, and Claudius knows that he has murdered the woman for whom he gave his soul.

The “leit motifs” sound out clearly once again as Hamlet begs Horatio to live :—

> “O, good Horatio, what a wounded name,
> Things standing thus unknown, shall live behind me !
> If thou didst ever hold me in thy heart,
> Absent thee from felicity awhile,
> And in this harsh world draw thy breath in pain,
> To tell my story.”

“The rest is silence ;” and as we look down upon the peaceful face we think of the gentle, generous, kindly, dreamy boy of the first Act, of his beautiful love for his father, his reaching up to God, and we know that all the misery he caused—the cruelty of the murders of poor Rosencrantz and Guildenstern, the madness and death of Ophelia—were due to the o’erwrought brain, the mind unbalanced by the nightmare of a dreadful duty, and our hearts go out to the dead as we whisper with Horatio—

> “Good-night, sweet prince,
> And flights of Angels sing thee to thy rest !”

DIGESTION AND DIET.

By Ralph W. Wilson, M.D.

The subject of this paper is one that comes within the experience of us all ; it deals with a necessity of our lives ; and most of us, naturally, have formed opinions about it. But, when we compare our experiences in the matter, one with another, we find that they differ a good deal, and a wide field for discussion and controversy is thereby created. Although the processes involved in digestion are, presumably, dependent upon laws of Nature which are constant and fixed, the individuals upon whom these laws operate vary so much that it is difficult to lay down rules for exact guidance in all cases. When we come to close quarters with the subject, and try to comprehend, for example, the intricacies of organic chemistry presented in the case, or, the vital processes which underlie them, it seems quite impossible for us to get beyond mere general principles. We find, under apparently the same conditions, such pronounced differences, that, although digestion *may* be the same, on broad lines, in one man as in another, or, in man comparatively with the lower animals, the details are hardly reconcilable. One person discovers that he cannot eat eggs without suffering pain and sickness, another is nauseated by milk, and a third cannot eat shell-fish else he will have an attack of nettle-rash.

Now, peculiarities like these have a real existence. Some of them may be morbid developments which, at the outset, might have been checked or modified ; but, they are not entirely fanciful ; they are the outcome of complexities reached in the evolution of digestion in man.

Our knowledge of individuals in other respects makes clear that they do vary one from another in a high degree ; and so, we are the better prepared to recognise differences also, in their powers of digestion. To lay down hard and fast rules, therefore, to apply to everyone alike would soon bring trouble. More than that, the same individual changes in the course of his life-time, and what may well apply to one period of it, does not, necessarily, apply to another. The requirements of the body in infancy and childhood are not the same as when maturity has been reached. The rapid growth in the first stages of life requires more pabulum for accretion than when growth comes to a stop; and the diminishing activities of old age call for less food still.

But even here we find many exceptions; for, some children eat very little and thrive; and some old people eat a very great deal, and continue to live comfortably.

To dogmatise about the details of diet and digestion, therefore, would be unwise; but, at the same time, certain general principles can be seen to run through the whole subject, and these may be stated as sure ground for action.

One of these principles is, that our bodies, like all other machines which do work, consume material for that purpose. Every muscular act, in speech or locomotion, and every movement and function performed within, by heart, lungs, brain, is brought about through the agency of food. The actual waste of living tissue in the process is slight. The source of power is the potential energy of the food-stuffs, which may be looked upon as storage substances flowing in a tidal manner among the tissues of the body. And, to get actual energy out of them in the shape of heat and mechanical work, they have to be broken up into their constituant chemical elements. Of the two sources of dissipation of energy in the body, *work* accounts for one fifth and *heat* for four fifths of it.

But, between the crude material of food outside the body, and the substances ready for assimilation which circulate within, and bathe, as it were, its various tissues and organs, there are many changes brought about by the digestive processes. The digestive organs themselves must, therefore, be described in a superficial way, and then, the changes wrought by them on the food-stuffs, if we wish at all to grasp the subject.

The digestive tube may be looked upon as a continuous whole with parts devoted to special purposes—stomach, colon, etc., are only dilatations of this tube. It is lined throughout by mucous membrane, and, receives the secretions and juices of a great number of glands. But this mucous membrane is the medium of absorption as well as of secretion.

Outside the mucous membrane is a muscular coat, by which the movements necessary for propulsion and for churning within the stomach are brought about. And between these layers the blood-vessels, lymphatics, and nerves ramify.

In different parts of its course the glands in its walls present different characters—in the mouth there are mucous and large salivary, glands. Then outside all, in the region of stomach and intestines, there is a tough membrane called the peritoneum. Now, this digestive tube, though contained within the body, is, in a manner, outside of it, and its mucous membrane is external to the tissue-mass. Food that is lying within it has to be absorbed from its mucous surface before it can penetrate the body-substance and partake of the work it is destined to fulfil.

The mouth receives juices from the glands that open into it, and the term "saliva" is applied to the whole of these secretions. In this saliva there is a ferment, *ptyalin*, which digests the starchy element of food. Then, in the stomach the glands secrete gastric juice, the ferment of which is *pepsin*, and pepsin acts upon the proteid matter of food, by which is meant the fibre of meat, the white of egg, etc. Next, there is a secretion of bile from the liver, and this is received into the first part of the small intestine along with the pancreatic juice. Both pancreatic juice and bile digest fats. The pancreatic juice, with its ferment *trypsin*, digests likewise both starches and proteids, *i.e.*, farinaceous and meat foods. And, finally, there is an intestinal juice containing a ferment, *invertin*, which digests cane-sugar.

Food, as a term, is applied to every form of nutriment that we consume, and the kinds of materials from which it is obtained, viewed chemically, can be reduced to five. They are classified as *proteids*, *carbo-hydrates*, *fats*, *salts*, and *water*.

Water, salts, and fats are so well known that they need no explanation. But proteids, stated simply, are represented by such articles as butcher's meat, although it is contained in other animal and vegetable products as well. Carbo-hydrates are represented by bread, potatoes and farinaceous foods in general. The difference in chemical composition between proteids and carbo-hydrates is that proteids contain nitrogen as well as carbon and hydrogen, and carbo-hydrates contain carbon and hydrogen only, as the name suggests.

Every kind of food has to be prepared for absorption into the body, and many chemical changes take place in the process —this is the function of digestion.

And first, we will consider digestion as it begins in the mouth, the mouth being a very important part of the mechanism. Food has to be reduced to a finely-divided state by mastication and mixed with salivary juices before it can be rightly swallowed; and the action of the jaws and teeth is in this respect, all-important. Though mastication may be hurriedly done by some people with no evil consequences, haste in swallowing is a habit to be avoided, nevertheless. As the starchy foods, like bread, rice, and potatoes are converted into sugar in the mouth by an elaborate process in which dextrins are first formed, a fair amount of time is required for its accomplishment. If it is not done properly, it runs the risk of passing on into the large intestine and there, giving rise to gaseous distension and pain—this being the result of the fermentation of unconverted starch.

The function of saliva is principally mechanical, however. The medium in which it works is alkaline, and as the process can only go on under alkaline conditions, the importance of efficient mastication is seen at once; for, the mass, when swallowed, enters the acid medium of the gastric juice. In its passage through the stomach, therefore, the action of saliva on starch is arrested.

The whole of the time at my disposal might profitably be devoted to matters connected with the first stage of digestion; and at the risk of making this part of the subject disproportionate, I will enter into a few details.

A great statesman once said that we should chew each morsel of food thirty-two times; and, upon the whole, he was rather below than above the mark, if perfect digestion is to be maintained into old age. Food ought to be so well masticated that it will be swallowed involuntarily, and if this object was always aimed at, fermentative troubles farther on would be averted. The need for pills and correctives, too, would hardly then exist, and the vendors of proprietary medicines would have reduced incomes.

The *way* to eat ought to be a matter for instruction and be taught to children in our present luxurious state of existence. Not only should parents study what is best in the matter of food for them, but they should also superintend this first stage of digestion, and establish the important habit of efficient mastication.

It is this initial stage of digestion which is associated with voluntary control; and, probably, the sense of pleasure which accompanies eating, has been a contributary means of encouraging the act. Hunger seems not to have been enough in itself to induce efficient feeding. The proper development of the species required the pleasures of the palate as well, to complete the ends of evolution. It is not unlikely, however, in civilised life, that this pleasurable side of digestion may be exercised and cultivated too much, so that the inducement to eat arises from the gratification of eating rather than from the discomforts of starvation. If such be the case, there is additional need for supervision in the feeding of children.

One sometimes hears it said that children may be left entirely to their instinct in this matter. But a very little observation will, I think, convince us of the fallacy of this view. If left to himself a child will generally bolt his food and consume inordinate quantities of sugar and pastry, with the inevitable result of catarrh of stomach and intestines. Out of this condition arises a kind of self-poisoning in which both mind and body suffer.

These so-called instincts were more reliable in savage times, perhaps, than they can be now. The pangs of hunger impelled people then to find food—a task entailing hard work and sometimes danger—and the enjoyment of eating it was, probably, a secondary consideration to the satisfaction of appeasement. But, with the advance of civilisation, and the acquisition of new luxuries, the sensations of taste and the pleasures of the palate were stimulated, and began to preponderate. The child of the cave-man gnawed his bone and probably enjoyed it; but he thereby strengthened his jaws and his teeth. His only sweets would be the sugar which he obtained from ripe fruits and from the nuts and starchy seeds which were yet in a primitive stage of cultivation.

The child of civilisation, on the other hand, has sugar in its crystalline form, extracted from beet-root and cane in quantities unlimited. Instead of fruits coming only after the summer ripening, and lasting but for a short time, they are now brought from every land in greater variety than ever, and at all seasons of the year.

The instincts, then, which were evolved under harder conditions of existence than now prevail, and still survive in us in corrupt form, are scarcely to be trusted to as safe guides in dieting.

To maintain our bodies in their primitive state of physical perfection, on the lines which Nature has followed, we ought to leave off a good deal of our spoon-feeding after infancy, and cultivate a little more the gnawing propensities of our early fore-fathers. The teeth in these degenerate days, decay, because they are so little used; and the jaws which hold them diminish in size and strength for the same reason. A hard biscuit or crust of bread to eat, would be better than a score of sponge cakes in this connection.

When the food has passed beyond the mouth and beyond the control of the will, there is no longer a sense of pleasure in the acts of digestion. The process goes on automatically and unconsciously. In children the greatest sense of pleasure appears to be associated with mass; their gastric craving is gratified by lumps, and the bolting of unmasticated mouthfuls is sure to take place if they are not closely watched by guardians or parents. The pre-occupation of their minds with matters pertaining to their sports and games may in some measure account for this; but the fact remains that there is too much bolting of food.

Did the digestive powers of early life continue to the end it might not matter much whether the food were bolted or not—for children can romp and play after meals with impunity. But the powers of digestion seem to flag as life advances, and if the habit of rapid eating has become established, dyspepsia and flatulancy will be the result later on.

Food, then, undergoes considerable preparation in the mouth by mastication and by the action of saliva. When the stomach is reached the food enters an acid medium, and in this the pepsin ferment begins to act, the principal result being the peptonisation of meat-fibre, or, of what we have called proteids and albumens. Then it passes into the small intestine where it meets with bile and pancreatic juice. The ferment, *trypsin*, of the pancreatic juice, acts in an alkaline medium once more, converting starches into sugar and meats into peptones; so that it is a reserve power behind the mouth and stomach ready to complete the unfinished work of both. But, even then, under certain conditions, some portions of food remain undigested, and then we get trouble in the large intestine farther on. Microbes in great variety exist in both small and large intestines, and undigested food is sure to be acted upon there by these agents. In the case of starch, volumes of gas are evolved, and in the case of albumens sometimes deadly poisons are produced, the alkaloid muscarin being one of them.

The importance of giving each of our digestive organs the right kind and the right quantity of food then, can at once be seen. Their powers of digestion are limited, and if we pass this limit, considerable mischief may result. But to hurry over this part of the digestive process which is, to the majority, pretty well known, let us consider what takes place when digestion is complete.

The small intestine, many feet in length, has its surface thrown into folds, which greatly increases its area. Its extent has been calculated to be about eleven square yards, and on this surface there are projections called *villi*, which are the chief organs of absorption. So numerous are the villi, amounting to four or five millions in all, that they still further increase the superficies of it. Absorption of the fluid food goes on, however, in every part of the digestive tract, and large quantities can thus be dealt with.

Now, how does the food, prepared by digestion, reach the various tissues and organs throughout the body? The substances to be absorbed must be diffusible, and the epithilial cells which line the mucous membrane and villi have the power to absorb the favourable material or oppose the absorption of the unfavourable. The channels by which this diffusible material enters the system are the blood-vessels and lymph-vessels with which the villi are well supplied.

I referred to the selective power of the epithilial cells;

there is probably a still greater selective power in the lymphoid cells; and these act as filtering media. Harmful substances are kept out, or at least, retarded in their entrance, and suitable substances received, by this agency. Through the blood-vessels pass the proteid matter, sugar, salts, and water; and through the lymph-vessels the greater part of the fats. The blood-vessels pass on their contents into the portal vein which reaches the liver; and the chyle vessels pass on the fats into the thoracic duct, which in its turn opens into the venous system.

What happens to this food-matter when it has been absorbed is not yet well understood. We know that the liver converts some of the material brought to it into sugar, but what the changes are which take place from the point of absorption to the point where the food material is cast out again no exact knowledge exists. We get *work* and *heat* out of it, that we know, and this is brought about by chemical action. The food-matter is broken up; some of it is used by the tissues as a source of energy, and for repair, and the rest is cast out as waste products. These waste products take the form of carbon di-oxide and urea; but it all suggests that vital activity, so far as we can comprehend it, is a state of interchange of the atoms and molecules of which both the living body-mass and the non-living food-mass are composed.

It is on this account that the food question has to be approached from the chemical side, and the unfamiliar titles of *proteid* and *carbo-hydrate* can therefore hardly be avoided.

But, as the popular mind has been fascinated of late by such intricate physical and chemical problems as those connected with the examination of Radium, it may be forgivable to speak to an Educational Union of the elements of which our own bodies are composed. And the glimpses into molecular change as it occurs in the one will help towards a better comprehension of the other, let us hope.

I will ask you, accordingly, to think of living tissues, whether it be brain, muscle, or bone, as substances (protoplasm) composed of chemical elements which are undergoing constant change of combination and relative position. These chemical elements are not numerous, and may be considered by us here as being four in number, namely, carbon, hydrogen, nitrogen,

and oxygen. There are traces of other elements as well, such as sulphur, phosphorus and iron, but the first four are the principal ones.

Now, when a typical carbo-hydrate (dextrose) is analysed, it is found to be composed of six atoms of carbon, twelve of hydrogen, and six of oxygen ($C_6 H_{12} O_6$) in combination. This combination is called a molecule, and for it to be burned and give off heat, it requires O from an outside source to enter into combination with its elements, the result of which is the splitting up of the molecule of dextrose into CO_2 and $H_2 O$ (carbonic acid and water). That seems simple enough; but, the changes you can ring on even three elements if there is an unlimited supply of each, is beyond calculation.

I will, therefore, give you the approximate formula of a typical proteid and you will see how complicated organic chemistry may and does become. It is this: $C_{72} H_{112} N_{18} O_{22} S$; these are chemically combined. The number of atoms in this molecule are so numerous that the interchanges which are possible between it and living protoplasm are past finding out.

It is not to be wondered at that people quarrel over such a complicated question. And, accordingly, in the matter of food and dietetics it will be as well for us to proceed on the broadest lines. There are just a few points further to be elucidated before we can proceed to the question of the food itself.

To have a complete mental picture, even in outline, of the process of digestion, a word ought to be said about the digestive juices. The glands that secrete these juices derive their supply from the blood which circulates within them; matter is selected from this nutritive fluid, which enables the gland-cells to perform their functions. In the mouth, saliva is secreted by several large glands whose ducts open into the mouth-cavity. Now, the amount of this secretion is rather astonishing—1½ litre (2½ pints), is secreted, on an average, every twenty-four hours; and 7 litres (12 pints) of gastric juice are secreted in the same period, *i.e.*, one-tenth of the body weight. But nearly all this fluid-secretion after it has performed its work of reducing and changing the food into a liquid mass, is itself absorbed again. There is, therefore, a tidal flow of fluid, from the blood as a source, into the digestive tube, and after it has been swelled in volume by the food elements, it returns whence it came, and entering the general circulation, is propelled once more by the heart to every organ and tissue of the body.

There is another slowly-moving fluid besides the blood, however, which participates in the whole process, *i.e.*, the *lymph*, which has an extensive series of vessels of its own. If we trace, in imagination, both blood and lymph to their ultimate destination, we conceive them as bathing every tissue of the body with nutrient fluid. Whatever a particular tissue may want is there at its surface, or ought to be, ready to be given to it; and, if the food supply is adequate and of the right quality, the chemical affinities and vital selections will do the rest. An organ like the brain probably requires a lot of fat; an organ like a muscle, something similar to itself; and the bones require lime-salts.

No single food that we know, save perhaps the milk with which an animal feeds its young, contains all the elements of nutrition in approximately right proportions. The development of the human organism has become so complex compared with its surroundings, that there is no single food-stuff available in the world which will supply all that it needs. The nutritive supply has to be obtained from many sources, and the tissues themselves allowed to do the selection.

The classification of nutrients, therefore, into *proteids*, *carbo-hydrates*, *fats*, *salts*, and *water*, enables us to understand the subject better than by thinking of them in terms of the multitudinous food-stuffs in use.

Popularly we speak of food in terms of chops and steaks, bread-and-butter, and so forth; but, if the individual tissues of our bodies had conscious thought they would think of food in terms of C. H. N. and O., and their combinations. Such complex chemical combinations as the proteids are represented in butcher's meat, the white of eggs, milk, etc., on the animal side, and to some degree in bread, peas, rice, potatoes and carrots, etc., on the vegetable side. Now, in a diet composed of such substances as these, the amount of proteid in each that could be absorbed would vary greatly. Of the total amount of proteid in beef the whole of it would be absorbed with the exception of about 2½ per cent., and the same would be the case for eggs. In the case of milk there would be 7½ per cent. not absorbed; in peas, 17 per cent.; in rice, 20 per cent.; in bread, 21 per cent.; potatoes, 30 per cent.; and carrots, 39 per cent. not absorbed.

The absorbability of different foods, therefore, comes to be a question of the greatest importance. That which is not absorbed has to be dealt with in the body and cast out, and the excretory organs are called into requisition. One may tax the capacity of these and soon get into the realm of disease. But it is one of the principles to be understood, that, though a particular food-stuff may contain a large amount of any element needed, it does not follow that that element will be absorbed, *in toto*, when presented as a diet.

The carbo-hydrates, in general, are very completely absorbed; sugar is especially so, and starch, like that contained in rice, has a high degree of absorbability. It is such starches as are contained in green vegetables which give the greatest difficulty to our digestive organs.

Then fat, according as it is fluid or solid at ordinary temperatures, is more or less absorbable. Cream and butter are more absorbable than bacon or mutton, fat.

But of all these articles of diet only a certain amount of each is required in the day. There is such a thing as over-feeding as well as under-feeding, and a standard of diet depends very much upon what a person has to do—a navvy requires more carbo-hydrates than a policeman. And, as to energy-production, fat represents more than twice as much as either proteids or carbo-hydrates.

There is one thing about a mixed diet which it is useful to know, and that is, that a *mixture* promotes absorbability; and this influence is greater on the absorbability of proteids than of the others. Bread and milk are better absorbed when taken together than when taken separately. And the same applies to a combination of milk and cheese.

Although complete absorbability is not desirable—a moderate residue being best—yet, when the non-absorbable matter is in great excess it costs a deal of muscular energy to get rid of it. This tells against an exclusively vegetable diet.

(To be continued.)